



CUMM:115

## SPECIFICATION

Be it known that I, Frank M. Csulits, have invented a certain new and useful  
**METHOD AND APPARATUS FOR AUTHENTICATING DOCUMENTS**  
**INCLUDING CURRENCY** of which the following is a specification.

<b>"EXPRESS MAIL" MAILING LABEL</b>	
Number:	<u>EF008279285US</u>
Date of Deposit:	<u>10/4/94</u>
<i>I hereby certify that this paper or fee is being deposited with the United States Postal Service as "Express Mail Post Office To Addressee" Service under 37 C.F.R. §1.10 on the date indicated above and is addressed to the Honorable Commissioner of Patents and Trademarks, Washington, D.C. 20231</i>	
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## METHOD AND APPARATUS FOR AUTHENTICATING DOCUMENTS INCLUDING CURRENCY

### BACKGROUND OF THE INVENTION

#### Cross-Reference to Related Applications

This application is a continuation-in-part of pending United States patent application Serial No. 08/219,093 filed March 29, 1994 for a "Currency Discriminator and Authenticator." United States patent application Serial No. 08/219,093 is a continuation-in-part of United States patent application Serial No. 08/127,334 filed September 27, 1993, for a "Method and Apparatus for Currency Discrimination and Counting" which is a continuation of United States patent application Serial No. 07/885,648, filed on May 19, 1992, and issued as United States Patent No. 5,295,196, for a "Method and Apparatus for Currency Discrimination and Counting," which is a continuation-in-part of abandoned United States patent application Serial No. 07/475,111, filed February 5, 1990, for a "Method and Apparatus for Currency Discrimination and Counting."

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#### Field of the Invention

The present invention relates, in general, to document authentication. More specifically, the present invention relates to an apparatus and method for authenticating documents such as currency bills by illuminating the documents with ultraviolet light.

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### Background

A number of methods have been developed for authenticating the genuineness of security documents. These methods include sensing magnetic, optical, conductive, and other characteristics of documents under test. In general, it has been found that no single authentication test is capable of detecting all types of counterfeit documents while at the same time not rejecting any genuine documents. Therefore, more than one test may be employed whereby a first test is used to detect certain types of counterfeits and additional tests are used to detect other types of counterfeits.

It has been known that the illumination of certain substances with ultraviolet light causes the substances to fluoresce, that is, to emit visible light. Some documents employ fluorescent materials as a security feature to inhibit counterfeiting. Typically, these fluorescent security features comprise a marking which is visibly revealed when the document is illuminated with ultraviolet light. Previous methods have been developed to authenticate such documents by sensing the fluorescent light emitted by a document illuminated by ultraviolet light and comparing the sensed fluorescent light to the fluorescent light emitted by genuine documents.

Conversely, some documents, such as United States currency, are manufactured from special paper designed not to fluoresce under ultraviolet light. Previously known authenticating methods for such documents have sensed for the emission of fluorescent light under ultraviolet illumination and have rejected as counterfeit those documents emitting fluorescent light.

However, it has been found that the presently known ultraviolet authentication methods do not detect all types of counterfeits. For example, while many counterfeit

United States bills do emit fluorescent light under ultraviolet illumination, some counterfeit United States bills do not.

### **SUMMARY OF THE INVENTION**

5 It is an object of the present invention to provide an improved method and apparatus for authenticating documents including currency documents.

It is another object of the present invention to provide an improved method and apparatus for authenticating United States currency bills.

10 It is another object of the present invention to provide an improved method and apparatus for authenticating documents which may be employed in a currency discriminating apparatus.

It is an object of the present invention to provide an improved method and apparatus for authenticating documents including currency documents by illuminating a document with ultraviolet light.

15 It is another object of the present invention to provide an improved method and apparatus for authenticating documents which improves the ability of a system to accurately reject improper documents while reducing the likelihood of rejecting genuine documents.

Briefly, the objectives enumerated above are achieved according to a preferred 20 embodiment of the present invention by illuminating a document to be authenticated with ultraviolet light and measuring the amount of ultraviolet light which is reflected off the document. Based on the amount of ultraviolet light which is detected, the document is either authenticated or rejected. In the case of documents being

authenticated relative to United States currency, a bill is rejected if a high level of reflected ultraviolet light is not detected.

In another preferred embodiment, the above objectives are achieved by illuminating a document with ultraviolet light and measuring both the amount of reflected ultraviolet light and the amount of emitted visible light. Based on the amount of ultraviolet light detected and the amount of visible light detected, a document is either authenticated or rejected. In the case of documents being authenticated relative to United States currency, a bill is rejected if either a high level of reflected ultraviolet light is not detected or even a low level of visible light is detected.

As explained above, it is known that some counterfeit United States bills fluoresce, or emit visible light, when illuminated by ultraviolet light. As genuine United States currency does not fluoresce, the emission of visible light has been employed as a means of detecting counterfeit United States currency. However, it has been found that not all counterfeit United States bills fluoresce; and hence, such counterfeits will not be detected by the above described fluorescence test.

It has been found that genuine United States currency reflects a high level of ultraviolet light when illuminated by an ultraviolet light source. It has also been found that some counterfeit United States bills do not reflect a high level of ultraviolet light. Such counterfeit bills may or may not also fluoresce under ultraviolet light. The present invention employs an authentication test wherein the amount of reflected ultraviolet light is measured and a bill is rejected if it does not reflect a high amount of ultraviolet light. By employing such a test, counterfeit

United States bills which do not reflect a high level of ultraviolet light may be properly rejected.

While not all counterfeit United States bills fail to reflect a high level of ultraviolet light and hence not all counterfeit United States bills will be detected using 5 this test, the present invention provides an additional means for detecting counterfeit bills which might otherwise go undetected. Furthermore, the likelihood of a counterfeit United States bill going undetected may be further reduced by employing an alternative embodiment of the present invention wherein both the amount of reflected ultraviolet light and the amount of emitted visible light are measured. In 10 such a system, a bill is rejected as counterfeit if either it fails to reflect a high level of ultraviolet light or it fluoresces.

The above described embodiments may be adapted to authenticate currencies from other countries and other types of documents such as food stamps and checks. For instance some genuine documents may be designed to reflect ultraviolet light only 15 in certain locations and/or in a predetermined pattern. An alternative embodiment of the present invention may be designed to accept documents which exhibit similar characteristics while rejecting those which do not. Likewise, an alternative embodiment of the present invention may be employed to authenticate documents based on both their characteristics with respect to reflected ultraviolet light and their 20 characteristics with respect to fluorescent emissions, e.g., detecting the amount, location, and/or pattern of fluorescent emissions.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent upon reading the following detailed description in conjunction with the drawings in which:

5 FIG. 1A is a side view of a preferred embodiment of a document authenticating system according to the present invention;

FIG. 1B is a top view of the preferred embodiment of FIG. 1A along the direction 1B;

10 FIG. 1C is a top view of the preferred embodiment of FIG. 1A along the direction 1C; and

FIG. 2 is a functional block diagram illustrating a preferred embodiment of a document authenticating system according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGs. 1A-1C, there is shown a side view of a preferred embodiment of a document authenticating system according to the present invention, a top view of the preferred embodiment of FIG. 1A along the direction 1B, and a top view of the preferred embodiment of FIG. 1A along the direction 1C, respectively. An ultraviolet ("UV") light source 102 illuminates a document 104. Depending upon the characteristics of the document, ultraviolet light may be reflected off the document and/or fluorescent light may be emitted from the document. A detection system 106 is positioned so as to receive any light reflected or emitted toward it but not to receive any UV light directly from the light source 102. The detection system 106 comprises a UV sensor 108, a fluorescence sensor 110, filters, and a plastic housing. The light source 102 and the detection system 106 are both mounted to a

printed circuit board 112. The document 104 is transported in the direction indicated by arrow A by a transport system (not shown). The document is transported over a transport plate 114 which has a rectangular opening 116 in it to permit passage of light to and from the document. In a preferred embodiment of the present invention, 5 the rectangular opening 116 is 1.375 inches (3.493 cm) by 0.375 inches (0.953 cm). To minimize dust accumulation onto the light source 102 and the detection system 106 and to prevent document jams, the opening 116 is covered with a transparent UV transmitting acrylic window 118. To further reduce dust accumulation, the UV light source 102 and the detection system 106 are completely enclosed within a housing 10 114 (not shown) comprising the transport plate 114.

Referring now to FIG. 2, there is shown a functional block diagram illustrating a preferred embodiment of a document authenticating system according to the present invention. FIG. 2 shows an UV sensor 202, a fluorescence sensor 204, and filters 206, 208 of a detection system such as the detection system 106 of FIG. 1. 15 Light from the document passes through the filters 206, 208 before striking the sensors 202, 204, respectively. An ultraviolet filter 206 filters out visible light and permits UV light to be transmitted and hence to strike UV sensor 202. Similarly, a visible light filter 208 filters out UV light and permits visible light to be transmitted and hence to strike fluorescence sensor 204. Accordingly, UV light, which has a 20 wavelength below 400 nm, is prevented from striking the fluorescence sensor 204 and visible light, which has a wavelength greater than 400 nm, is prevented from striking the UV sensor 202. In a preferred embodiment the UV filter 206 transmits light having a wavelength between about 260 nm and about 380 nm and has a peak transmittance at 360 nm. In a preferred embodiment, the visible light filter 208 is a

blue filter and preferably transmits light having a wavelength between about 415 nm and about 620 nm and has a peak transmittance at 450 nm. The above preferred blue filter comprises a combination of a blue component filter and a yellow component filter. The blue component filter transmits light having a wavelength between about 5 320 nm and about 620 nm and has a peak transmittance at 450 nm. The yellow component filter transmits light having a wavelength between about 415 nm and about 2800 nm. Examples of suitable filters are UG1 (UV filter), BG23 (blue bandpass filter), and GG420 (yellow longpass filter), all manufactured by Schott. In a preferred embodiment the filters are about 8 mm in diameter and about 1.5 mm 10 thick.

The UV sensor 202 outputs an analog signal proportional to the amount of light incident thereon and this signal is amplified by amplifier 210 and fed to a microcontroller 212. Similarly, the fluorescence sensor 204 outputs an analog signal proportional to the amount of light incident thereon and this signal is amplified by 15 amplifier 214 and fed to a microcontroller 212. Analog-to-digital converters 216 within the microcontroller 212 convert the signals from the amplifiers 210, 214 to digital and these digital signals are processed by the software of the microcontroller 212. The UV sensor 202 may be, for example, an ultraviolet enhanced photodiode sensitive to light having a wavelength of about 360 nm and the fluorescence sensor 204 may be a blue enhanced photodiode sensitive to light having a wavelength of 20 about 450 nm. Such photodiodes are available from, for example, Advanced Photonix, Inc., Massachusetts. The microcontroller 212 may be, for example, a Motorola 68HC16.

The exact characteristics of the sensors 202, 204 and the filters 206, 208 including the wavelength transmittance ranges of the above filters are not as critical to the present invention as the prevention of the fluorescence sensor from generating an output signal in response to ultraviolet light and the ultraviolet sensor from generating an output signal in response to visible light. For example, instead of, or in addition to, filters, a authentication system according to the present invention may employ an ultraviolet sensor which is not responsive to light having a wavelength longer than 400 nm and/or a fluorescence sensor which is not responsive to light having a wavelength shorter than 400 nm.

10 Calibration potentiometers 218, 220 permit the gains of amplifiers 210, 214 to be adjusted to appropriate levels. Calibration may be performed by positioning a piece of white fluorescent paper on the transport plate 114 so that it completely covers the rectangular opening 116 of FIG. 1. The potentiometers 218, 220 may then be adjusted so that the output of the amplifiers 210, 214 is 5 volts.

15 The implementation of the preferred embodiment of a document authenticating system according to the present invention as illustrated in FIG. 2 with respect to the authentication of U.S. currency will now be described. As discussed above, it has been determined that genuine United States currency reflects a high level of ultraviolet light and does not fluoresce under ultraviolet illumination. It has also been 20 determined that under ultraviolet illumination counterfeit United States currency exhibits one of the four sets of characteristics listed below:

- 1) Reflects a low level of ultraviolet light and fluoresces;
- 2) Reflects a low level of ultraviolet light and does not fluoresce;
- 3) Reflects a high level of ultraviolet light and fluoresces;

4) Reflects a high level of ultraviolet light and does not fluoresce.

Counterfeit bills in categories (1) and (2) may be detected by a currency authenticator employing an ultraviolet light reflection test according to a preferred embodiment of the present invention. Counterfeit bills in category (3) may be detected by a currency authenticator employing both an ultraviolet reflection test and a fluorescence test according to another preferred embodiment of the present invention. Only counterfeits in category (4) are not detected by the authenticating methods of the present invention.

According to a preferred embodiment of the present invention, fluorescence is determined by any signal that is above the noise floor. Thus, the amplified fluorescent sensor signal 222 will be approximately 0 volts for genuine U.S. currency and will vary between approximately 0 and 5 volts for counterfeit bills depending upon their fluorescent characteristics. Accordingly, an authenticating system according to a preferred embodiment of the present invention will reject bills when signal 222 exceeds approximately 0 volts.

According to a preferred embodiment of the present invention, a high level of reflected UV light ("high UV") is indicated when the amplified UV sensor signal 224 is above a predetermined threshold. The high/low UV threshold is a function of lamp intensity and reflectance. Lamp intensity can degrade by as much as 50% over the life of the lamp and can be further attenuated by dust accumulation on the lamp and the sensors. The problem of dust accumulation is mitigated by enclosing the lamp and sensors in a housing as discussed above. An authenticating system according to a preferred embodiment of the present invention tracks the intensity of the UV light source and readjusts the high/low threshold accordingly. The

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degradation of the UV light source may be compensated for by periodically feeding a genuine bill into the system, sampling the output of the UV sensor, and adjusting the threshold accordingly. Alternatively, degradation may be compensated for by periodically sampling the output of the UV sensor when no bill is present in the

5 rectangular opening 116 of the transport plate 114. It is noted that a certain amount of UV light is always reflected off the acrylic window 118. By periodically sampling the output of the UV sensor when no bill is present, the system can compensate for light source degradation. Furthermore, such sampling could also be used to indicate to the operator of the system when the ultraviolet light source has burned out or

10 otherwise requires replacement. This may be accomplished, for example, by means of a display reading or an illuminated light emitting diode ("LED"). The amplified ultraviolet sensor signal 224 will initially vary between 1.0 and 5.0 volts depending upon the UV reflectance characteristics of the document being scanned and will slowly drift downward as the light source degrades. In an alternative preferred

15 embodiment to a preferred embodiment wherein the threshold level is adjusted as the light source degrades, the sampling of the UV sensor output may be used to adjust the gain of the amplifier 210 thereby maintaining the output of the amplifier 210 at its initial levels.

It has been found that the voltage ratio between counterfeit and genuine U.S. bills varies from a discernable 2-to-1 ratio to a non-discernable ratio. According to a preferred embodiment of the present invention a 2-to-1 ratio is used to discriminate between genuine and counterfeit bills. For example, if a genuine U.S. bill generates an amplified UV output sensor signal 224 of 4.0 volts, documents generating an amplified UV output sensor signal 224 of 2.0 volts or less will be rejected as

counterfeit. As described above, this threshold of 2.0 volts may either be lowered as the light source degrades or the gain of the amplifier 210 may be adjusted so that 2.0 volts remains an appropriate threshold value.

According to a preferred embodiment of the present invention, the 5 determination of whether the level of UV reflected off a document is high or low is made by sampling the output of the UV sensor at a number of intervals, averaging the readings, and comparing the average level with the predetermined high/low threshold. Alternatively, a comparison may be made by measuring the amount of UV light reflected at a number of locations on the bill and comparing these 10 measurements with those obtained from genuine bills. Alternatively, the output of one or more UV sensors may be processed to generate one or more patterns of reflected UV light and these patterns may be compared to the patterns generated by genuine bills. Such a pattern generation and comparison technique may be performed by modifying an optical pattern technique such as that disclosed in United States Pat. 15 No. 5,295,196 incorporated herein by reference in its entirety or in United States patent application Serial No. 08/287,882 filed August 9, 1994 for a "Method and Apparatus for Document Identification," incorporated herein by reference in its entirety.

In a similar manner, the presence of fluorescence may be performed by 20 sampling the output of the fluorescence sensor at a number of intervals. However, in a preferred embodiment, a bill is rejected as counterfeit U.S. currency if any of the sampled outputs rise above the noise floor. However, the alternative methods discussed above with respect to processing the signal or signals of a UV sensor or sensors may also be employed, especially with respect to currencies of other

countries or other types of documents which may employ as security features certain locations or patterns of fluorescent materials.

A currency authenticating system according to the present invention may be provided with means, such as a display, to indicate to the operator the reasons why a document has been rejected, e.g., messages such as "UV FAILURE" or "FLUORESCENCE FAILURE." A currency authenticating system according to the present invention may also permit the operator to selectively choose to activate or deactivate either the UV reflection test or the fluorescence test or both. A currency authenticating system according to the present invention may also be provided with means for adjusting the sensitivities of the UV reflection and/or fluorescence test, for example, by adjusting the respective thresholds. For example, in the case of U.S. currency, a system according to the present invention may permit the high/low threshold to be adjusted, for example, either in absolute voltage terms or in genuine/suspect ratio terms.

15 While the present invention has been described with reference to one or more particular embodiments, those skilled in the art will recognize that many changes may be made thereto without departing from the spirit and scope of the present invention, which is set forth in the following claims.